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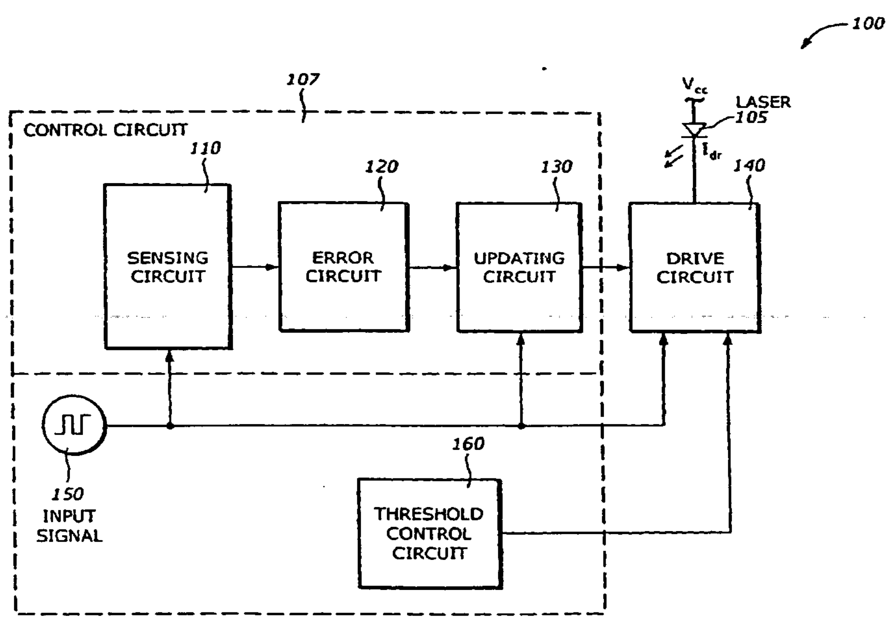
(54) Title: SUB-THRESHOLD BIAS CONTROL FOR BURST MODE OPTICAL TRANSMITTERS



(57) Abstract: The present invention is a method and apparatus for driving a laser in an optical transmitter. A sub-threshold circuit provides a sub-threshold current to adjust a bias current from a bias current source during an adjustment mode. A modulating circuit is coupled to the sub-threshold circuit to generate a first modulating current during an operational mode. The first modulating current includes a second modulating current and the sub-threshold current. The first modulating current and the bias current form a drive current to drive the laser.

WO 01/50640 A1

SUB-THRESHOLD BIAS CONTROL FOR BURST MODE OPTICAL TRANSMITTERS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to optical transmitters. In particular, the invention relates to drive circuit for optical transmitters.

2. Description of Related Art

Existing laser driver control circuits maintain a bias current either slightly above the laser threshold current to optimize the high speed properties of the laser, or with a bias current near zero to maximize the extinction ratio of the optical signal.

Traditional techniques for driving optical transmitters compromises the performance of the optical transmitters. Either the optical transmitter operates at high frequencies with low extinction ratio, or high extinction ratio and low frequencies. In addition, when the laser bias current is near zero, the junction capacitance of the laser must be fully charged or discharged while modulating the optical amplitude.

Therefore there is a need in the technology to provide an efficient method and apparatus to control the bias current in optical transmitters.

SUMMARY OF THE INVENTION

The present invention is a method and apparatus for driving a laser in an optical transmitter. A sub-threshold circuit provides a sub-threshold current to adjust a bias current from a bias current source during an adjustment mode. A modulating circuit is coupled to the sub-threshold circuit to generate a first modulating current during an operational mode. The first modulating current includes a second modulating current and the sub-threshold current. The first modulating current and the bias current form a drive current to drive the laser.

In a preferred embodiment, the sub-threshold circuit includes a sub-threshold current source and a sub-threshold switch, and the modulating current includes a modulating current source and a modulating switch. The sub-threshold current source generates the sub-threshold current at a predetermined level below a threshold level. The sub-threshold switch is coupled to the sub-threshold current source to connect the sub-threshold current source to the bias current source during the adjustment. The modulating current source

generates the second modulating current based on a modulating control quantity. The modulating switch is coupled to the modulating current source and the sub-threshold switch to connect the modulating current source and the sub-threshold current source to generate the first modulating current during the operational mode.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and advantages of the present invention will become apparent from the following detailed description of the present invention in which:

Figure 1 is a diagram illustrating an optical transmitter system which may utilize a drive circuit according to one embodiment of the invention.

Figure 2 is a diagram illustrating the drive circuit in Figure 1 according to one embodiment of the invention.

Figure 3A is a diagram illustrating a light-current characteristic during bias current adjustment according to one embodiment of the invention.

Figure 3B is a diagram illustrating a light-current characteristic after bias current adjustment according to one embodiment of the invention.

Figure 4 is a diagram illustrating the control circuit in Figure 1 according to one embodiment of the invention.

DESCRIPTION OF THE PRESENT INVENTION

The present invention is a method and apparatus for driving a laser in an optical transmitter. A sub-threshold circuit provides a sub-threshold current to adjust a bias current from a bias current source during an adjustment mode. A modulating circuit is coupled to the sub-threshold circuit to generate a first modulating current during an operational mode. The first modulating current includes a second modulating current and the sub-threshold current. The first modulating current and the bias current form a drive current to drive the laser.

In a preferred embodiment, the sub-threshold circuit includes a sub-threshold current source and a sub-threshold switch, and the modulating current includes a modulating current source and a modulating switch. The sub-threshold current source generates the sub-threshold current at a predetermined level below a threshold level. The sub-threshold switch is coupled to the sub-threshold current source to connect the sub-threshold current source to the bias current source during the adjustment. The modulating current source

generates the second modulating current based on a modulating control quantity. The modulating switch is coupled to the modulating current source and the sub-threshold switch to connect the modulating current source and the sub-threshold current source to generate the first modulating current during the operational mode.

The advantages of the invention include an improvement of the performance of burst mode optical transmitters by maintaining the bias current at a constant value below the laser threshold. The technique maintains the high frequency characteristics of the laser and maintains a very high extinction ratio. This is achieved by using a bias current that requires a small increase in current to attain lasing while remaining below the threshold current.

Figure 1 is a diagram illustrating an optical transmitter system 100 which may utilize a drive circuit according to one embodiment of the invention. The optical transmitter system 100 includes a laser 105, a control circuit 107, and a drive circuit 140.

The laser 105 is a semiconductor laser diode that emits optical radiation in response to a drive current I_{dr}. The drive current I_{dr} is generated by the drive circuit 140. The control circuit 107 generates control

quantities to control the drive circuit 140. The control circuit 107 includes a sensing circuit 110, an error circuit 120, an updating circuit 130, an input signal 150, and a threshold control circuit 160. The sensing circuit 110 senses the intensity of the optical radiation emitted by the laser 105 and generates a photodiode current proportional to the radiation intensity. The error circuit 120 generates an error voltage. The error voltage is the difference between a photodiode voltage proportional to the monitor photodiode current and a reference voltage. The updating circuit 130 receives the error voltage and generates control quantities to update the drive circuit. The drive circuit 140 generates the drive current according to the control quantities.

The input signal 150 provides the timing and clocking signal to the sensing circuit 110, the updating circuit 130, and the drive circuit 140. The threshold control circuit 160 provides a control signal to the drive circuit 140.

Figure 2 is a diagram illustrating the drive circuit in Figure 1 according to one embodiment of the invention. The drive circuit 140 includes a subthreshold circuit 210, a modulating circuit 220, and a bias current source 230.

The sub-threshold circuit 210 provides a sub-threshold current I_{st}. The sub-threshold circuit 210 includes a sub-threshold current source 215 and a sub-threshold switch S1 217. The sub-threshold current source 215 generates the sub-threshold current I_{st} at a predetermined current level. In one embodiment, this predetermined level is one incremental value below the threshold that is intended for the operation. The sub-threshold switch S1 217 is a three-terminal switch having two positions according to two modes: an adjustment mode and an operational mode. In the adjustment mode, the bias control loop is adjusted to provide a desired optical logic low level (e.g., logic 0). In the operational mode, the drive circuit 140 operates normally to drive the laser 105. In the adjustment mode, the sub-threshold switch S1 217 connects the sub-threshold current source 215 to the bias current source 230 so that the sub-threshold current I_{st} is added to the bias current I_b from the bias current source 230. This allows the optical low level to be large enough to be accurately detected and controlled. In practice, the optical low level is detected by measuring the current from a monitor photodiode in the sensing circuit 110. During operational mode, the sub-threshold switch S1 217 connects the sub-threshold current source 215 to the

modulating circuit 220 to form a modulating current as explained in the following.

The modulating circuit 220 provides a first modulating current I_{mod1}. The modulating circuit 220 includes a modulating current source 225 and a modulating switch S2 227. The modulating current source 225 generates a second modulating current I_{mod2}. In one embodiment, the modulating current source 225 is a current mode digital-to-analog converter (DAC). The current DAC receives digital data and converts this digital data into a corresponding current. The control digital data for the modulating current source 225 comes from the updating circuit 130 shown in Figure 1.

The switch S2 227 controls the modulation of the drive current I_{dr}. During the adjustment mode, the switch S2 227 is open to allow the sub-threshold current I_{st} to be added to the bias current I_b as discussed above. During the operational mode, the switch S2 227 is open or closed under the control of the input signal 150. The switch S2 227 is coupled to the switch S1 217 in the sub-threshold circuit 210. In the operational mode, the switch S1 217 connects the sub-threshold current source 215 to the modulating current source 225 to generate the first modulating current I_{mod1}. The first modulating current I_{mod1} is the sum of the second

modulating current I_{mod2} and the sub-threshold current I_{st}.

In the operational mode, when the switch S2 227 is open, the modulating current source 225 and the sub-threshold current source 215 are both disconnected from the bias current source 230. The drive current I_{dr} therefore is equal to the current provided by the bias current source 230 only, namely, the bias current I_b. This drive current $I_{dr} = I_b$ corresponds to a low output level. The adjustment of the bias current I_b is done with the sub-threshold current I_{st} and the low level is sufficiently large to be accurately detected and controlled during adjustment. When the switch S2 227 is closed, the modulating current source 225 and the sub-threshold current source 215 are both connected to the bias current source 230. The drive current I_{dr} therefore is equal to the sum of the currents provided by the bias current sources 230, the second modulating current Imod2, and the sub-threshold current I_{st}, namely, $I_b + I_{mod1} = I_b + I_{mod2} + I_{st}$. This sum current corresponds to an optical high level. When the switch S2 227 is controlled by the input signal 150, the switching of the switch S2 227 is synchronized with the low and high levels of the input signal 150 to produce a suitable drive current. When the input signal 150 is low, the switch S2 227 is open, corresponding to the low output

level. When the input signal 150 is high, the switch S2 227 is closed, corresponding to the high output level.

Figure 3A is a diagram illustrating a light-current characteristic during bias current adjustment according to one embodiment of the invention. The vertical axis represents the light intensity, or optical radiation, emitted by the laser and the horizontal axis represents the current that drives the laser. The optical level coincident with the horizontal axis represents the ideal low output level.

The light-current characteristic is represented by a straight line 310 defined by two points A and B. The line 310 also intersects the horizontal axis at point C. Point A corresponds to the optical low level L_L and point B corresponds to the optical high level L_H. During the bias adjustment, the current I_L corresponding to the optical low level L_L is equal to the sum of the I_b from the bias current source 230 shown in Figure 2 and the sub-threshold current I_{st}. Due to the addition of the sub-threshold current I_{st} in the adjustment, the resulting L_L is somewhat higher than the ideal low level.

Figure 3B is a diagram illustrating a light-current characteristic after bias current adjustment according to one embodiment of the invention.

The light-current characteristic is now represented by two segments DC and CB. The point D corresponds to the optical low level and the point B corresponds to the optical high level. Point B remains essentially the same as in Figure 3A. During operational mode, or after the adjustment, the current I_L corresponding to the optical low level L_L is equal to the bias current I_b from the bias current source 230 (In Figure 2) only. Since this bias current I_b is less than the sum I_b + I_{st}, the resulting I_L is less than the I_L set during the adjustment. Therefore the optical low level is now lower than the low level during the adjustment mode. The low level during generation is too low to detect. It is large enough to detect and control as in Figure 3A, but it is then adjusted down to a very small level in Figure 3B to maximize the extinction ratio.

Figure 4 is a diagram illustrating the control circuit 107 according to one embodiment of the invention. The control circuit 107 measures the intensity of the optical radiation emitted by the laser 110 and generates control digital data to the modulating and bias current sources 225 and 230. The control circuit 107 includes the sensing circuit 110, the error circuit 120, and the updating circuit 130 as shown in Figure 1. The control circuit 107 operates using a synchronous switching method. The sensing circuit 110

includes a monitor photodiode 410, a capacitor C 425, a switch S3 430, a reference bias current source 435, and a reference modulating current source 440. The error circuit 120 includes a transimpedance amplifier 450, a feedback resistor R 445, and an analog comparator 460. The updating circuit 130 includes a bias counter 470 and a modulating counter 480.

The monitor photodiode 410 senses the intensity of the optical radiation emitted by the laser 105 and generates a photodiode current proportional to the radiation intensity. The capacitor C 425 indicates junction capacitance associated with the photodiode 410. The transimpedance amplifier 450 and the feedback resistor R 445 forms a current-to-voltage amplifier to produce a voltage V_P corresponding to the filtered photodiode current. The voltage V_P therefore is also proportional to the light intensity as radiated by the laser 105. The voltage V_P then is applied to the comparator 460. The analog comparator 460 compares the voltage V_P with a reference voltage REF and generates an error voltage V_E.

The bias counter 470 is a counter that can count up (or increment) and count down (or decrement). The bias counter 470 has an up/down (U/D#) control input and a clock (CLK) input. When the U/D# input is at a low level, the bias counter 470 counts down, i.e.,

decrements. When the U/D# input is at a high level, the bias counter 470 counts up, i.e., increments. The bias counter 470 is clocked by a positive-going clock signal, i.e., the counting takes place at the positive-going transition of the clock signal. The bias counter 470 generates a bias digital count (CNTB) output. The CNTB output is a bias control quantity which is applied to the digital input of the current source 230 to control the generation of the bias current I_b.

The modulation counter 480 is essentially the same as the bias counter 470 except that the modulation counter 480 is negative-edge triggered, i.e., the counting takes place at the negative-going transition of the clock signal. The modulation counter 480 generates a modulating digital count (CNTM) output. The CNTM output is a modulating control quantity which is applied to the digital input of the modulating current source 225 to control the generation of the modulating current I_{mod2}. The number of bits of the counters 470 and 480 are predetermined and depends on the granularity of the control of the laser drive current. In one embodiment, the counters 470 and 480 are 8-bit up/down counters providing 256 counting values from 0 to 255.

The switch S3 430 is controlled by the input signal 150. In other words, the input signal 150 now drives the switch S3 430, the bias counter 470, the modulating

counter 480, and the switch S2 227 (in Figure 2) altogether. This scheme therefore assures synchronous operation of the entire system. The reference bias current source 435 provides a fixed current source I_{Pb} to the transimpedance amplifier 450 in the bias mode, i.e., when both switches S2 227 and S3 430 are open. The reference modulating current source 440 is connected to the switch S3 430 to provide a fixed modulating current I_{Pm} in the modulating mode, i.e., when both switches S2 227 and S3 430 are closed. The analog comparator 460 compares the V_P voltage with a fixed reference voltage to produce the error voltage V_E. The error voltage V_E is a digital signal that indicates the sign of the error. The counter direction is determined by V_E. The two counters 470 and 480 uses this error voltage V_E to update their count, at different clock edges. The outputs of these counters are used to control the current source 225 and 230 as in Figure 2.

The clock signals of the two counters 470 and 480 are tied together and connected to the input signal 150. Therefore the same input signal 150 is used to clock the two counters 470 and 480, at different clock edges, and to control the switch S2 227 in the output drive circuit 140.

The error voltage V_E in the control circuit 107 is changed synchronously with the switching of the switch

S1 and the updating of the two counters 470 and 480. Therefore, although both counters 470 and 480 are connected to the same error voltage, each counter is updated with different values of the error voltage V_E. The analog comparator 460 is a simple comparator because no precision matching is required. The switch S3 430 and the two reference current sources can be implemented by simple hardware. The transimpedance amplifier 450 and the analog comparator 460 form the error circuit 120 to generate the error quantity V_E to be used to update a control quantity as represented by the digital count output at each counter.

When the input signal 150 is at a low level, switches S2 227 and S3 430 are open. The drive current I_{dr} is equal to the bias current I_b. At the input side. the input current I_{TA} to the transimpedance amplifier 450 is equal to the sum of the photodiode current and the reference bias current I_{Pb}. The input current I_{TA} is converted to the V_P voltage by the transimpedance amplifier 450. Since the reference bias current I_{Pb} is fixed, the voltage V_P is still proportional to the photodiode current which in turn is proportional to the optical radiation emitted by the laser 105. The analog comparator 460 compares the V_P voltage with a fixed voltage and produces the error voltage V_E which controls the update of the bias counter 470. When the input

signal 150 transitions from a low level to a high level, the bias counter 470 is updated (i.e., increments or decrements) according to the value of the V_E. The bias current source 230 is therefore controlled accordingly.

When the input signal 150 is at a high level, both switches S2 227 and S3 430 are closed. The drive current I_{dr} is equal to the sum $I_b+I_{mod2}+ I_{st}$. The reference modulating current source 440 is connected to the input of the transimpedance amplifier 450. The input of the transimpedance amplifier 450 is now equal to the sum of the photodiode current, the reference bias current I_{Pb}, and the reference modulating current I_{Pm}. The transimpedance amplifier 450 converts this input current I_{TA} into the voltage V_P. Since I_{Pb} and I_{Pm} are fixed, the voltage V_P is proportional to the photodiode current which in turns is proportional to the optical radiation emitted by the laser 105. The analog comparator 460 compares the V_P voltage with a fixed voltage and produces the error voltage V_E. The error voltage V_E now corresponds to the photodiode current and the reference bias and modulating currents I_{Pb} and I_{Pm}. When the input signal 150 transitions from the high level to the low level, the modulating counter 480 is updated according to the error voltage V_E. The modulating current source 225 is then controlled by the mod counter 480.

It is seen that the error voltage V_E changes synchronously with the updating of the two counters 470 and 480. This is achieved by switching the reference current sources at the photodiode side synchronously with the input signal.

The control circuit 107 uses synchronous updating of the two counters. By using the input signal 150 as the clock signal for the bias counter 470 and the modulating counter 480, the laser drive circuit 140 controls the laser at precisely controlled times. The updating of the counters is synchronized with the switching of the drive current with a finite delay. The control circuit 107 therefore generates proper control without using a separate clock generator circuitry for the clocking of the two counters. The operation of the current sources is also synchronized with the switching of the drive current and the updating of the two counters. The result is a simple hardware structure with simple components.

Other modifications to the control circuit can be implemented. The threshold control circuit can be designed with variations of bias and modulation control circuitry. In addition, the sub-threshold current is not necessarily switched to the modulating current after bias current adjustment. The circuit can still operate but the high logic level will be affected.

While this invention has been described with reference to illustrative embodiments, this description is not intended to be construed in a limiting sense. Various modifications of the illustrative embodiments, as well as other embodiments of the invention, which are apparent to persons skilled in the art to which the invention pertains are deemed to lie within the spirit and scope of the invention.

CLAIMS

What is claimed is:

1. A method for driving a laser in an optical transmitter, the method comprising:

providing a sub-threshold current by a sub-threshold circuit to adjust a bias current from a bias current source during an adjustment mode; and

generating a first modulating current by a modulating circuit during an operational mode, the first modulating current including a second modulating current and the sub-threshold current, the first modulating current and the bias current forming a drive current to drive the laser.

2. The method of claim 1 wherein providing the sub-threshold current comprises:

generating the sub-threshold current at a predetermined level below a threshold level by a sub-threshold current source; and

connecting the sub-threshold current source to the bias current source during the adjustment mode by a sub-threshold switch.

3. The method of claim 2 wherein generating the first modulating circuit comprises:

generating the second modulating current based on a modulating control quantity by a modulating current source; and

connecting the modulating current source and the sub-threshold current source by a modulating switch to generate the first modulating current during the operational mode.

4. The method of Claim 3 wherein connecting the sub-threshold current source to the bias current source comprises controlling the sub-threshold switch by a threshold control circuit such that the sub-threshold current source is connected to the bias current source during the adjustment mode and to the modulating current source during the operational mode to provide the first modulating current.

5. The method of Claim 4 wherein the adjustment is performed during a time interval defined by a Full Service Access Network (FSAN) specification.

6. The method of Claim 5 wherein the threshold level is selected to separate an optical intensity from the laser into an optical high level and an optical low level.

7. The method of Claim 6 wherein the predetermined level is selected such that the optical low level is sufficiently large for accurate detection and control.

8. An apparatus for driving a laser in an optical transmitter, the apparatus comprising:

a sub-threshold circuit to provide a sub-threshold current to adjust a bias current from a bias current source during an adjustment mode, and

a modulating circuit coupled to the sub-threshold circuit to generate a first modulating current during an operational mode, the first modulating current including a second modulating current and the sub-threshold current, the first modulating current and the bias current forming a drive current to drive the laser.

9. The apparatus of claim 8 wherein the sub-threshold circuit comprises:

a sub-threshold current source to generate the sub-threshold current at a predetermined level below a threshold level; and

a sub-threshold switch coupled to the sub-threshold current source to connect the sub-threshold current

source to the bias current source during the adjustment mode.

10. The apparatus of claim 9 wherein the modulating circuit comprises:

a modulating current source to generate the second modulating current based on a modulating control quantity; and

a modulating switch coupled to the modulating current source and the sub-threshold switch to connect the modulating current source and the sub-threshold current source to generate the first modulating current during the operational mode.

11. The apparatus of Claim 10 wherein the sub-threshold switch is controlled by a threshold control circuit such that the sub-threshold current source is connected to the bias current source during the adjustment mode and to the modulating current source during the operational mode to provide the first modulating current.

12. The apparatus of Claim 11 wherein the adjustment is performed during a time interval defined by a Full Service Access Network (FSAN) specification.

13. The apparatus of Claim 12 wherein the threshold level is selected to separate an optical intensity from the laser into an optical high level and an optical low level.

14. The apparatus of Claim 13 wherein the predetermined level is selected such that the optical low level is sufficiently large for accurate detection and control.

15. An optical transmitter comprises:

a laser to emit an optical radiation in response to a drive current; and

a drive circuit to generate the drive current to drive the laser, the drive circuit comprising:

a sub-threshold circuit to provide a sub-threshold current to adjust a bias current from a bias current source during an adjustment mode, and

a modulating circuit coupled to the sub-threshold circuit to generate a first modulating current during an operational mode, the first modulating current including a second modulating current and the sub-threshold current, the first modulating current and the bias current forming the drive current to drive the laser.

16. The optical transmitter of claim 15 wherein the sub-threshold circuit comprises:

a sub-threshold current source to generate the sub-threshold current at a predetermined level below a threshold level; and

a sub-threshold switch coupled to the sub-threshold current source to connect the sub-threshold current source to the bias current source during the adjustment mode.

17. The optical transmitter of claim 16 wherein the modulating circuit comprises:

a modulating current source to generate the second modulating current based on a modulating control quantity; and

a modulating switch coupled to the modulating current source and the sub-threshold switch to connect the modulating current source and the sub-threshold current source to generate the first modulating current during the operational mode.

18. The optical transmitter of Claim 17 wherein the sub-threshold switch is controlled by a threshold control circuit such that the sub-threshold current source is connected to the bias current source during

the adjustment mode and to the modulating current source during the operational mode to provide the first modulating current.

19. The optical transmitter of Claim 18 wherein the adjustment is performed during a time interval defined by a Full Service Access Network (FSAN) specification.

20. The optical transmitter of Claim 19 wherein the threshold level is selected to separate an optical intensity from the laser into an optical high level and an optical low level.

21. The optical transmitter of Claim 20 wherein the predetermined level is selected such that the optical low level is sufficiently large for accurate detection and control.

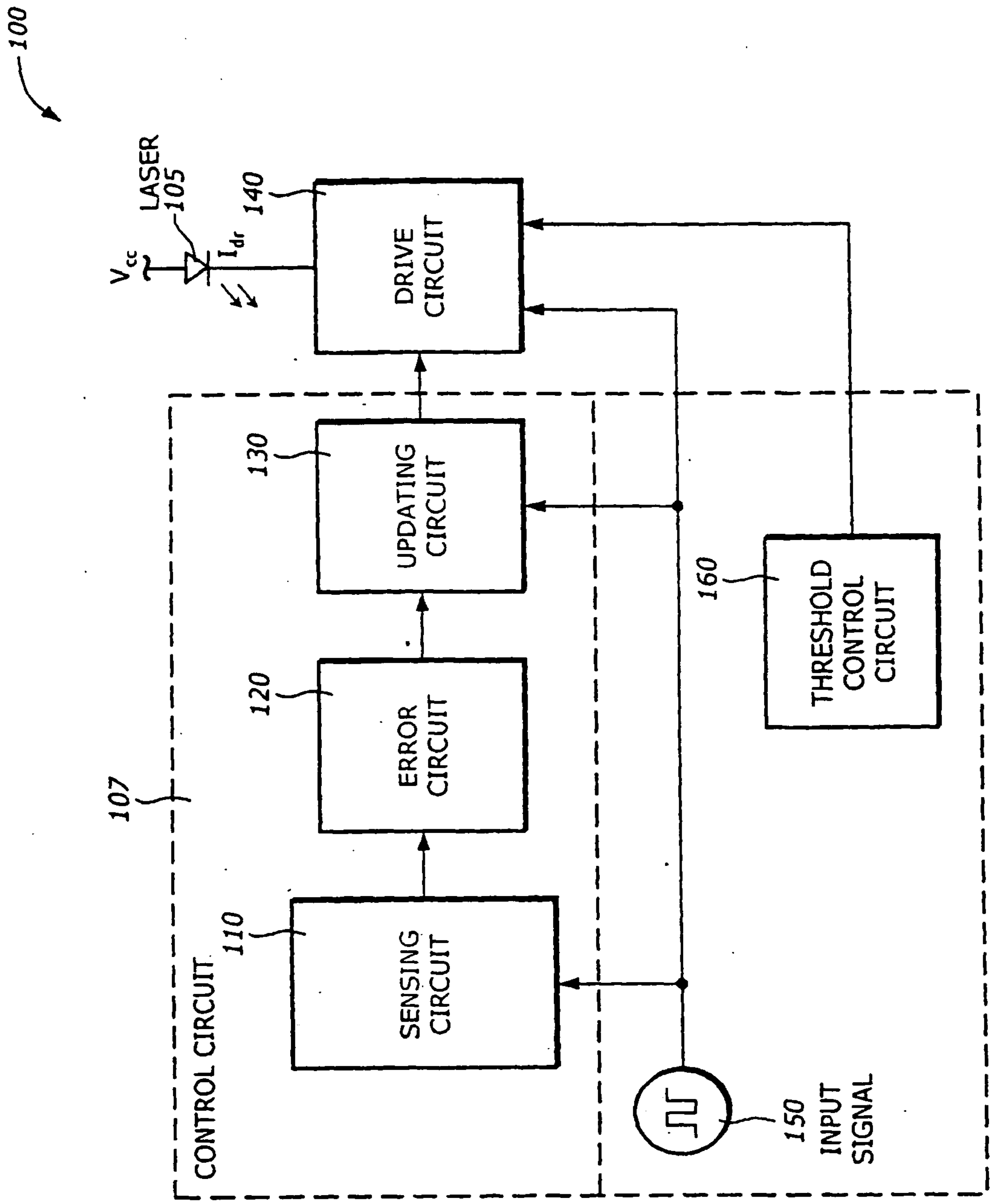

100
LASER
105
V_{cc}
I_{dr}
140
DRIVE CIRCUIT
130
UPDATING CIRCUIT
120
ERROR CIRCUIT
107
110
SENSING CIRCUIT
CONTROL CIRCUIT
160
THRESHOLD CONTROL CIRCUIT
150
INPUT SIGNAL

FIG. 1

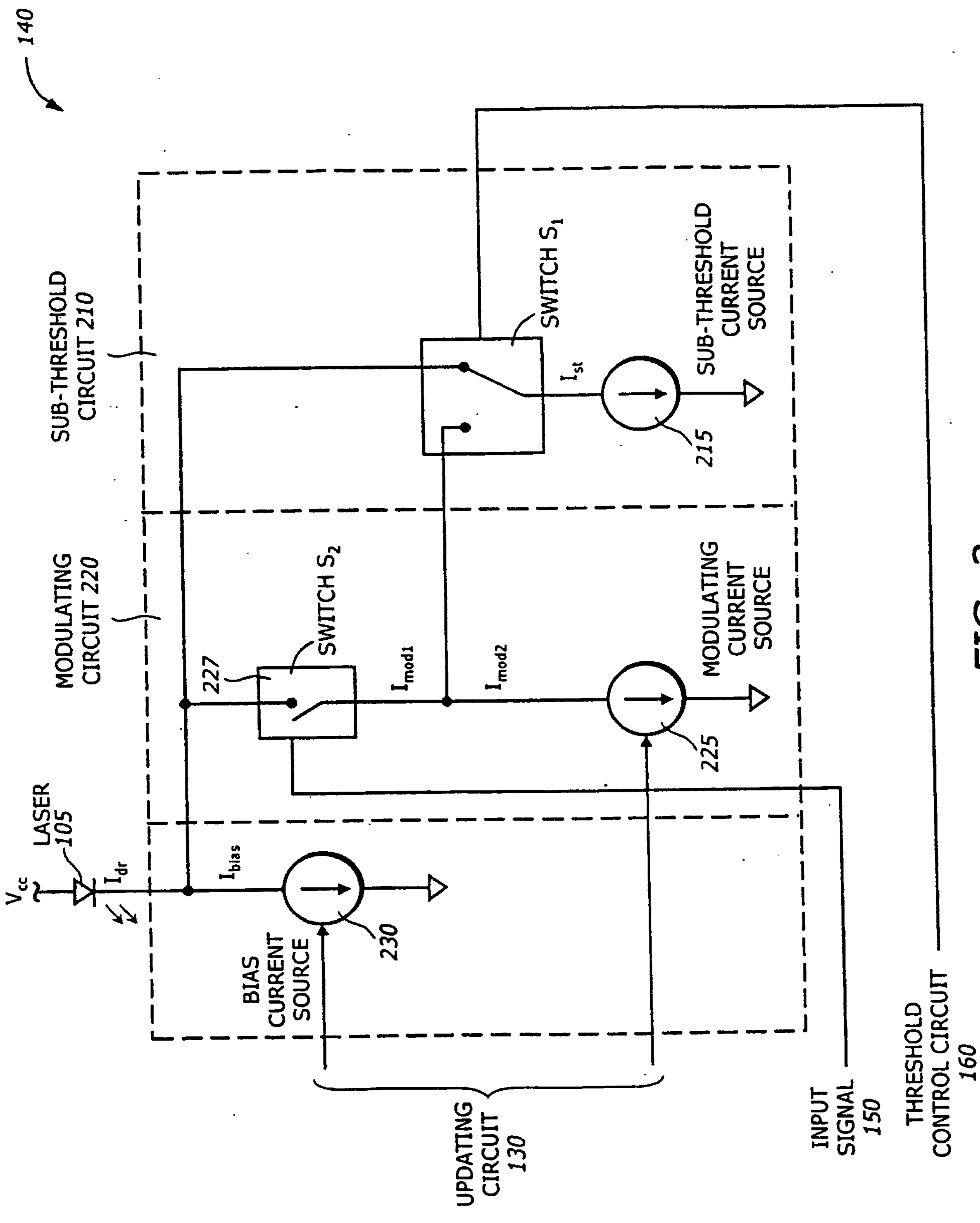

140
SUB-THRESHOLD CIRCUIT 210
MODULATING CIRCUIT 220
SWITCH S_1
SUB-THRESHOLD CURRENT SOURCE
I_{st}
215
SWITCH S_2
227
I_{mod1}
I_{mod2}
MODULATING CURRENT SOURCE
225
V_{cc}
LASER 105
I_{dr}
I_{bias}
BIAS CURRENT SOURCE
230
UPDATING CIRCUIT 130
INPUT SIGNAL 150
THRESHOLD CONTROL CIRCUIT 160

FIG. 2

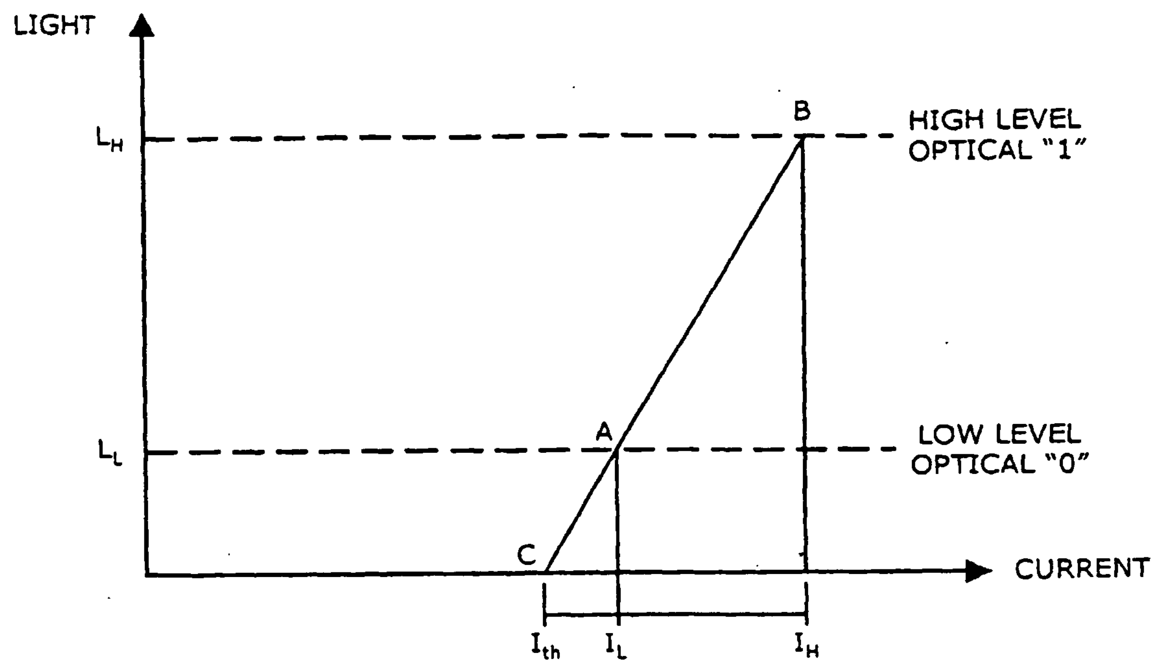

LIGHT
L_H
L_L
B
A
C
HIGH LEVEL OPTICAL "1"
LOW LEVEL OPTICAL "0"
CURRENT
I_{th}
I_L
I_H

FIG. 3A

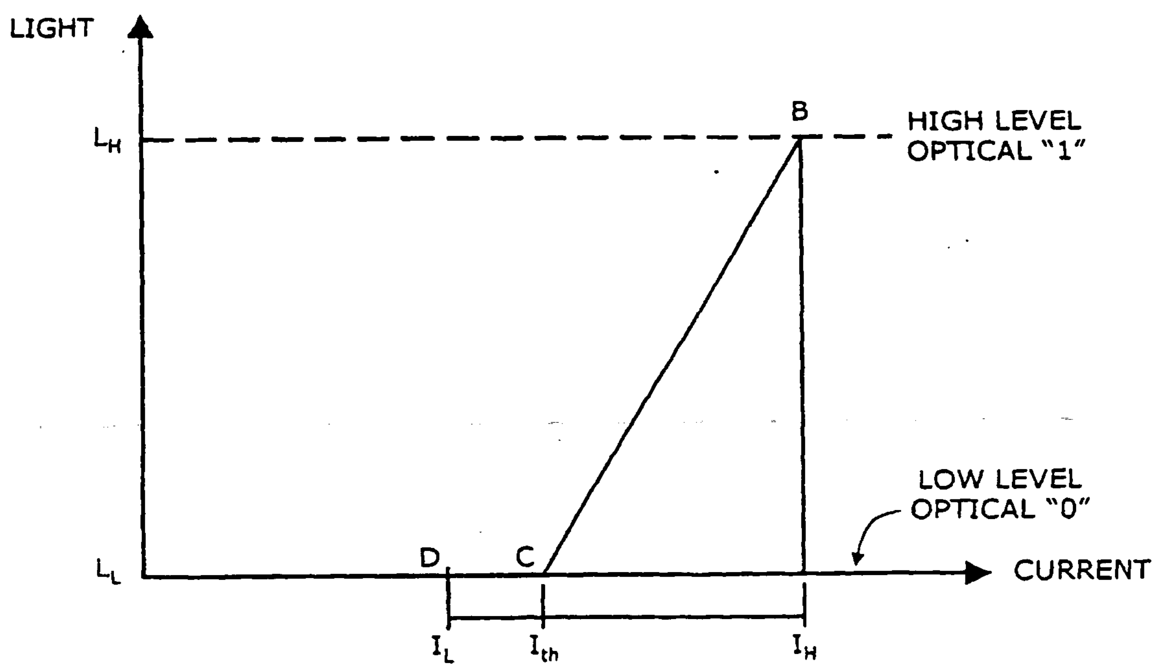

LIGHT
L_H
L_L
B
D
C
HIGH LEVEL OPTICAL "1"
LOW LEVEL OPTICAL "0"
CURRENT
I_L
I_{th}
I_H

FIG. 3B

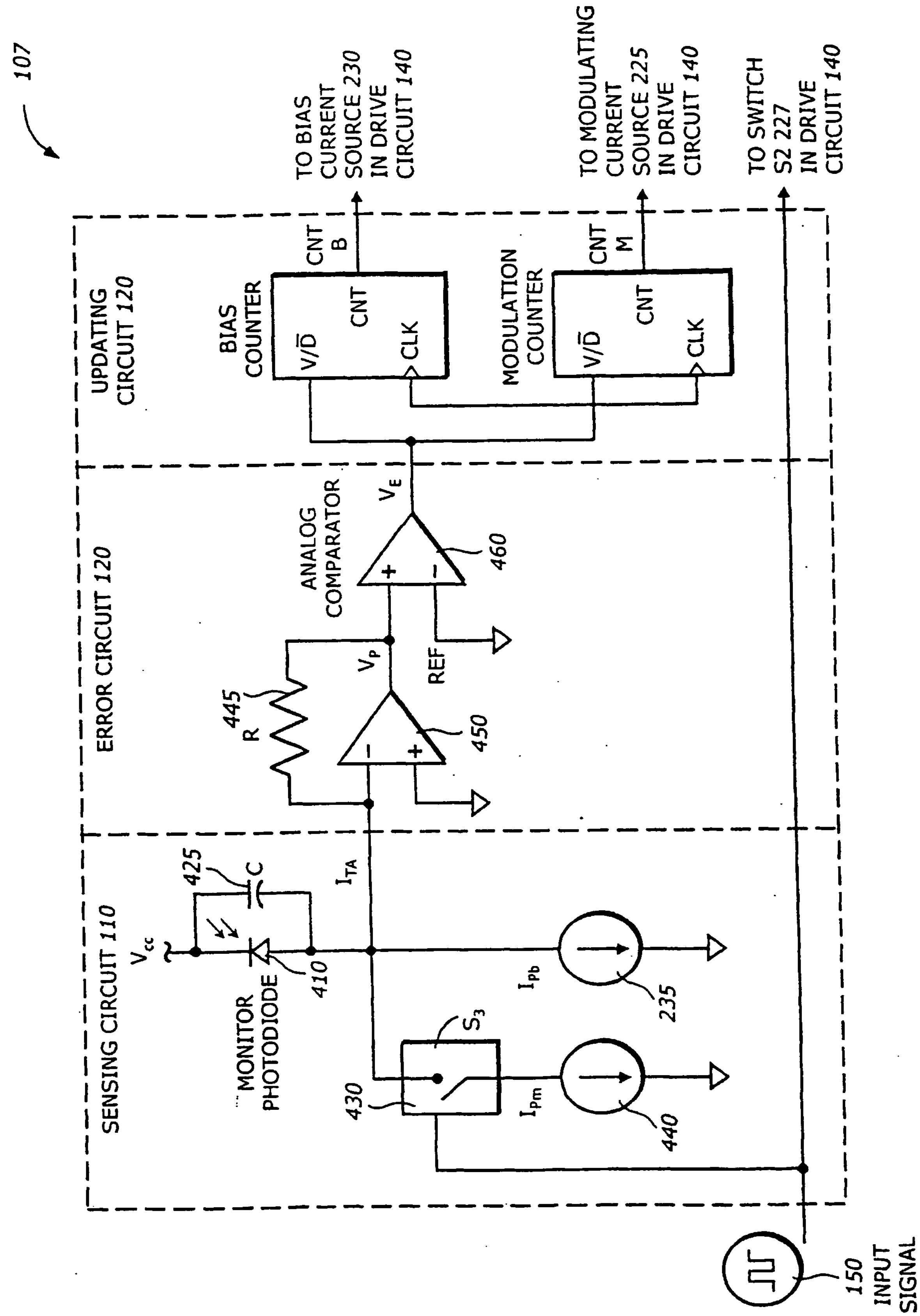

107
UPDATING CIRCUIT 120
BIAS COUNTER
V/$\overline{D}$
CNT
CLK
CNT B
TO BIAS CURRENT SOURCE 230 IN DRIVE CIRCUIT 140
MODULATION COUNTER
V/$\overline{D}$
CNT
CLK
CNT M
TO MODULATING CURRENT SOURCE 225 IN DRIVE CIRCUIT 140
TO SWITCH S2 227 IN DRIVE CIRCUIT 140
ERROR CIRCUIT 120
ANALOG COMPARATOR
V_E
460
445
R
V_P
REF
450
SENSING CIRCUIT 110
V_{cc}
425
C
MONITOR PHOTODIODE
410
I_{TA}
S_3
430
I_{Pb}
235
I_{Pm}
440
150
INPUT SIGNAL

FIG. 4

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/21786

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04B10/155 H01S5/0683

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04B H01S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5 526 164 A (KARL HUBERT ET AL) 11 June 1996 (1996-06-11) column 1, line 22 - line 52 column 3, line 25 - line 38 column 5, line 16 - line 62 column 7, line 15 - line 52 figures 1-3 ---	1-3, 6-10, 13-17, 20,21
Y	US 4 718 118 A (VIOLA JEFFREY P) 5 January 1988 (1988-01-05) column 4, line 18 - line 38 column 6, line 22 - line 59 figures 3-4C --- -/--	1-3, 6-10, 13-17, 20,21

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search	Date of mailing of the international search report
6 February 2001	14/02/2001

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/21786

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